



Harmonic Analysis of Selected Recycler ring Locations

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http://www-ap.fnal.gov/~yang/RR/CO041202/RR_3bump_041202_slides.pdf



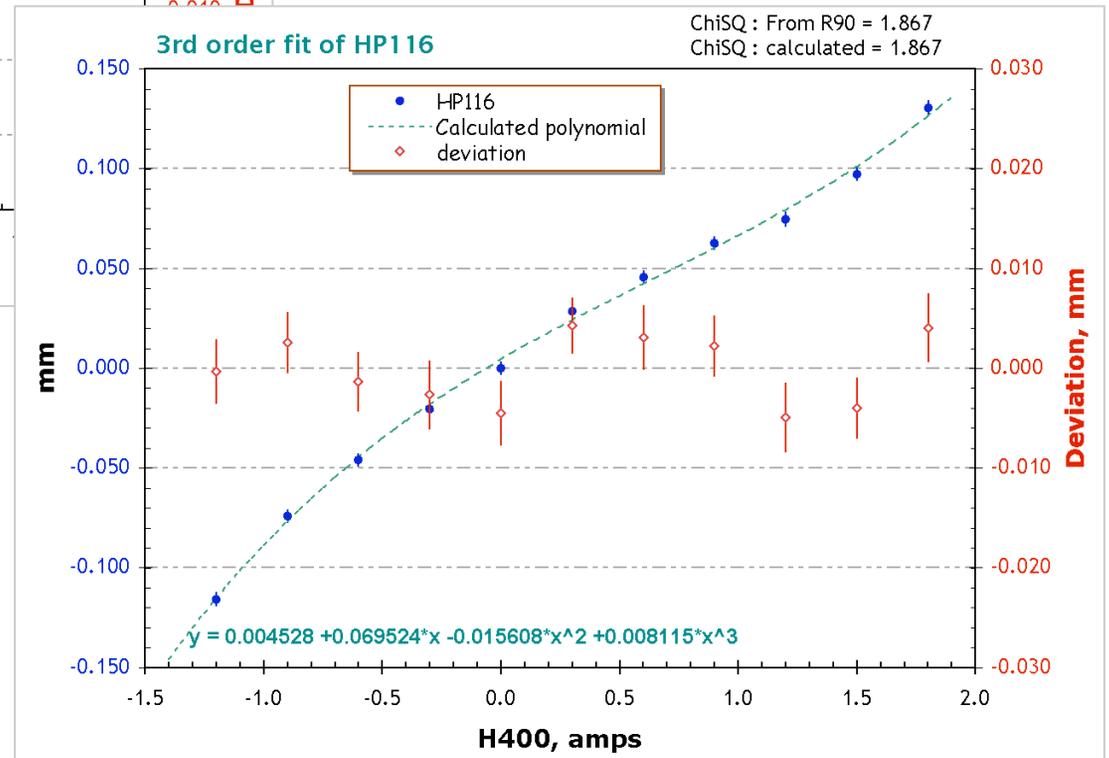
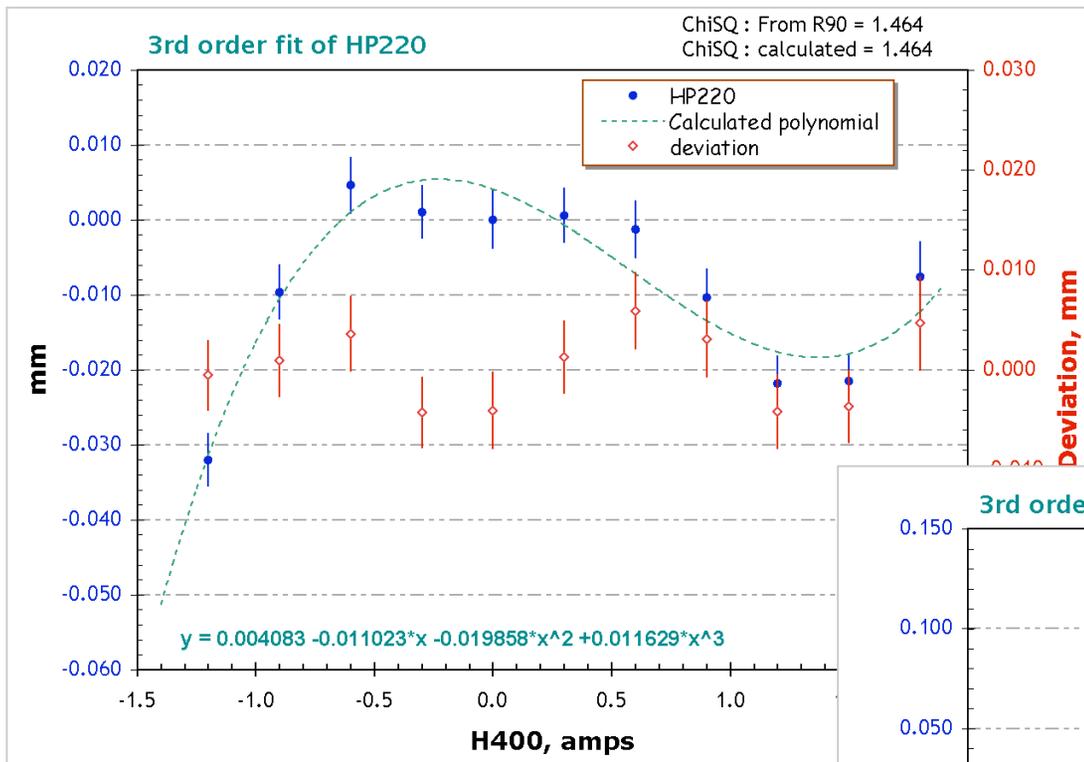
The study

- **Objective**
 - Take closed 3-bump orbit data.
 - Look for signs of local field errors.
- **Selected locations**
 - Locations implicated from previous study.
 - ✓ Lambertson: 402, 328, & 214.
 - ✓ RR620.
- **Use circulating proton beam**
 - Closed orbit data with 64 turns averaging.
 - Sample orbit with MI at 8-GeV.

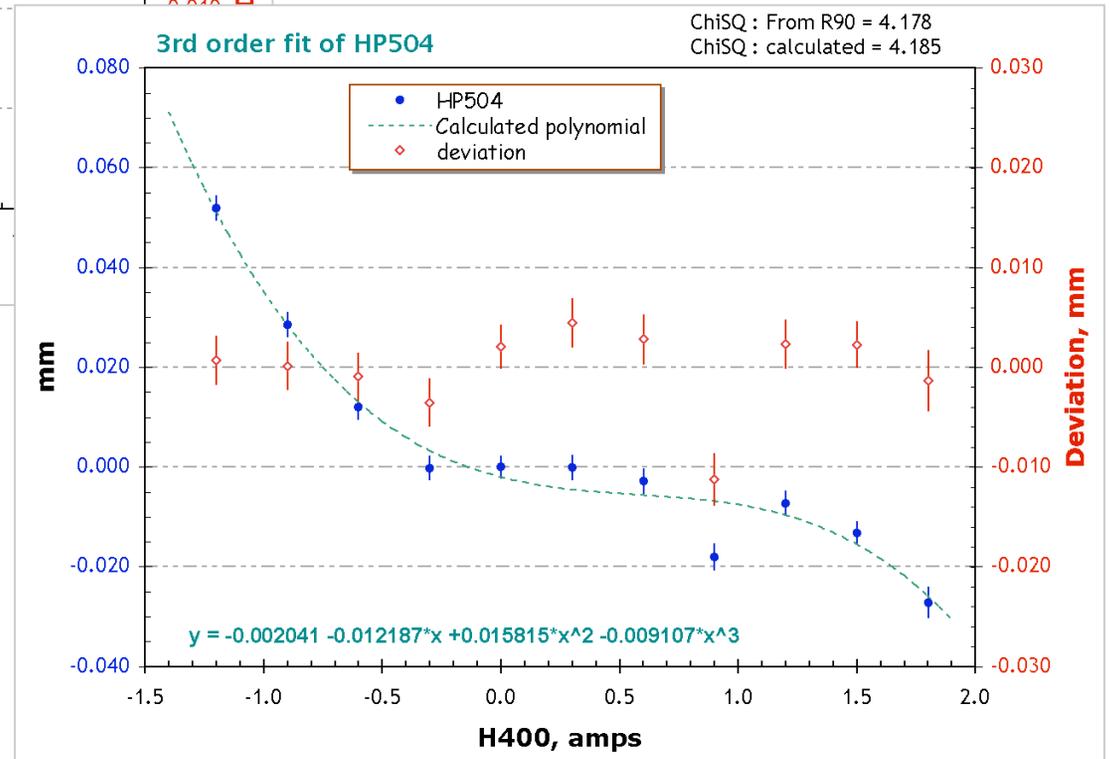
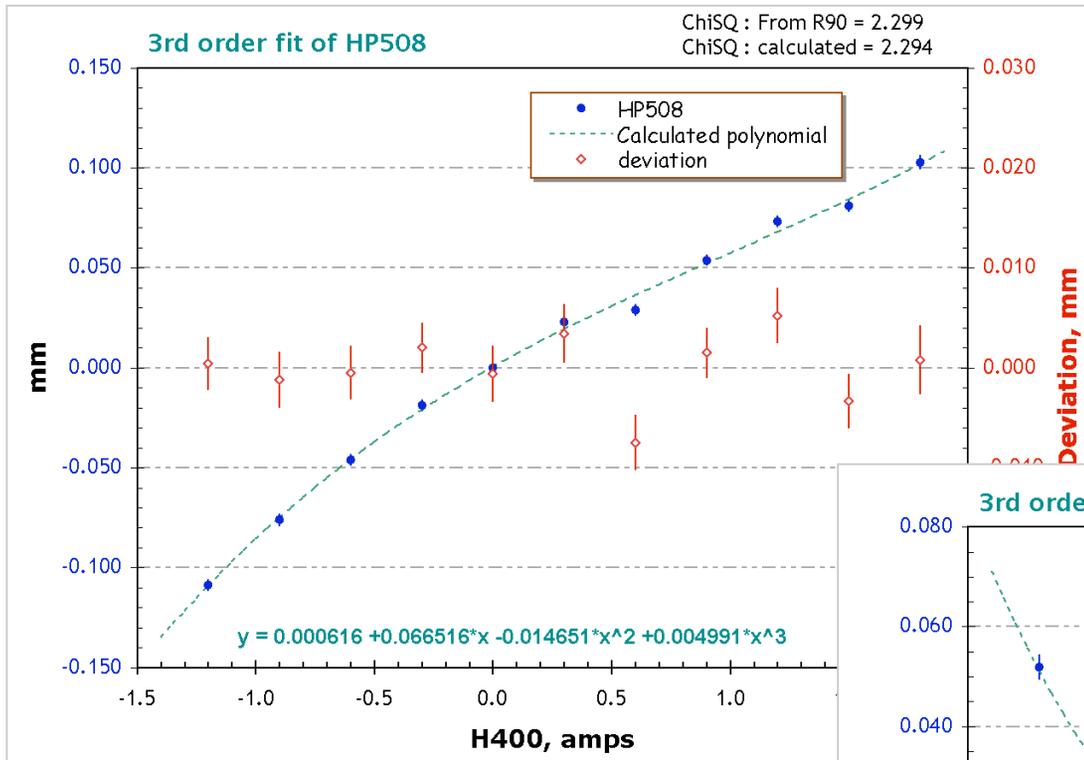
Data sets

- LAM402
 - ✓ H402:3
 - V401:3, & V403:3 (not conclusive)
- LAM328
 - ✓ H328:3
 - V327:3, & V329:3 (not analyzed)
- LAM214
 - ✓ H214:3
 - V213:3, & V215:3 (not analyzed)
- RR620
 - ✓ H620:3
 - V619:3, & V621:3 (not analyzed)

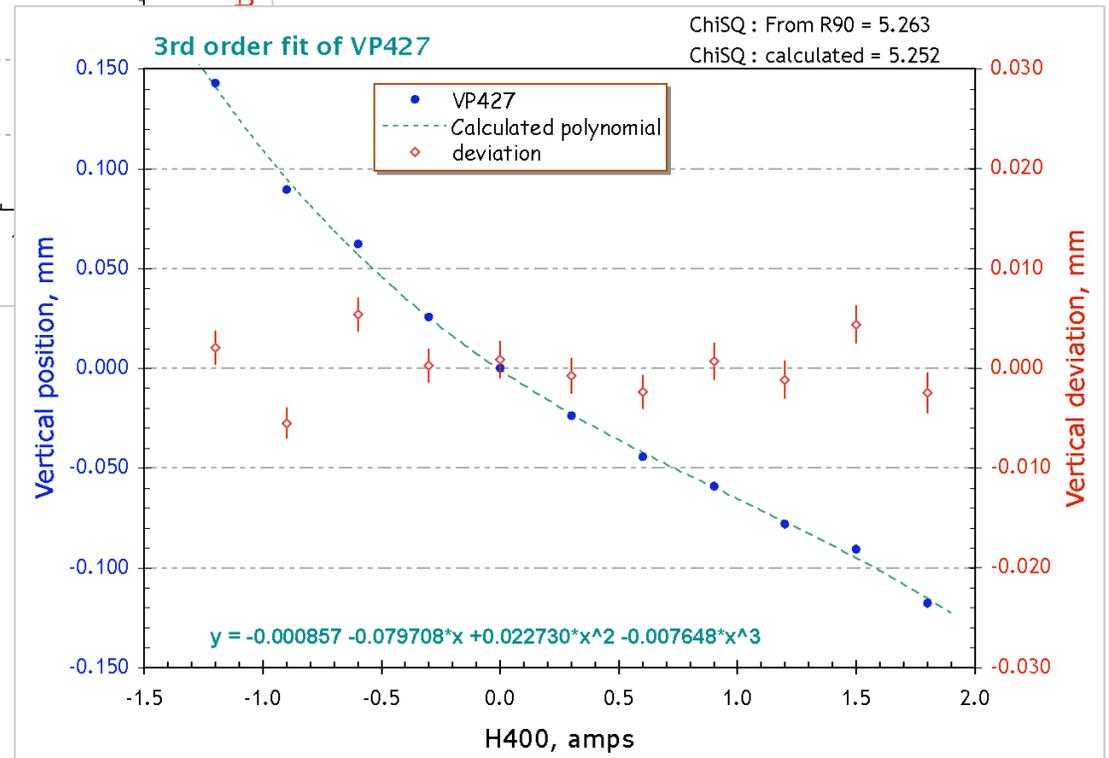
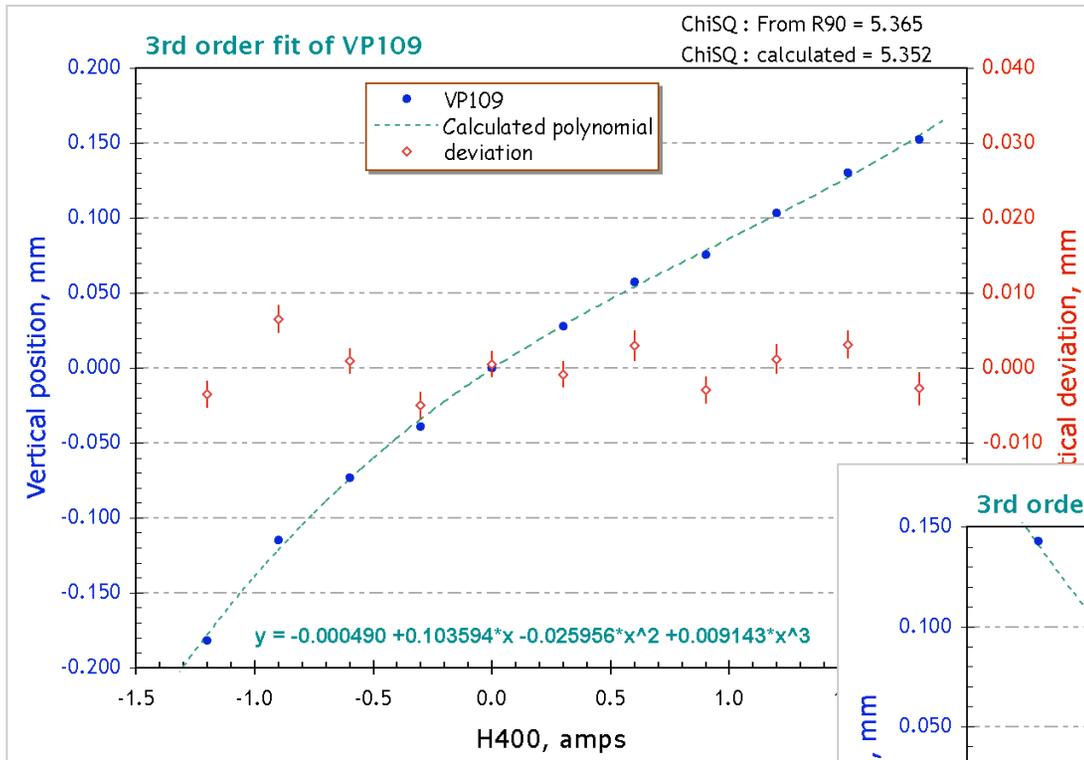
HP116 & HP220 responses to H402 3-bump



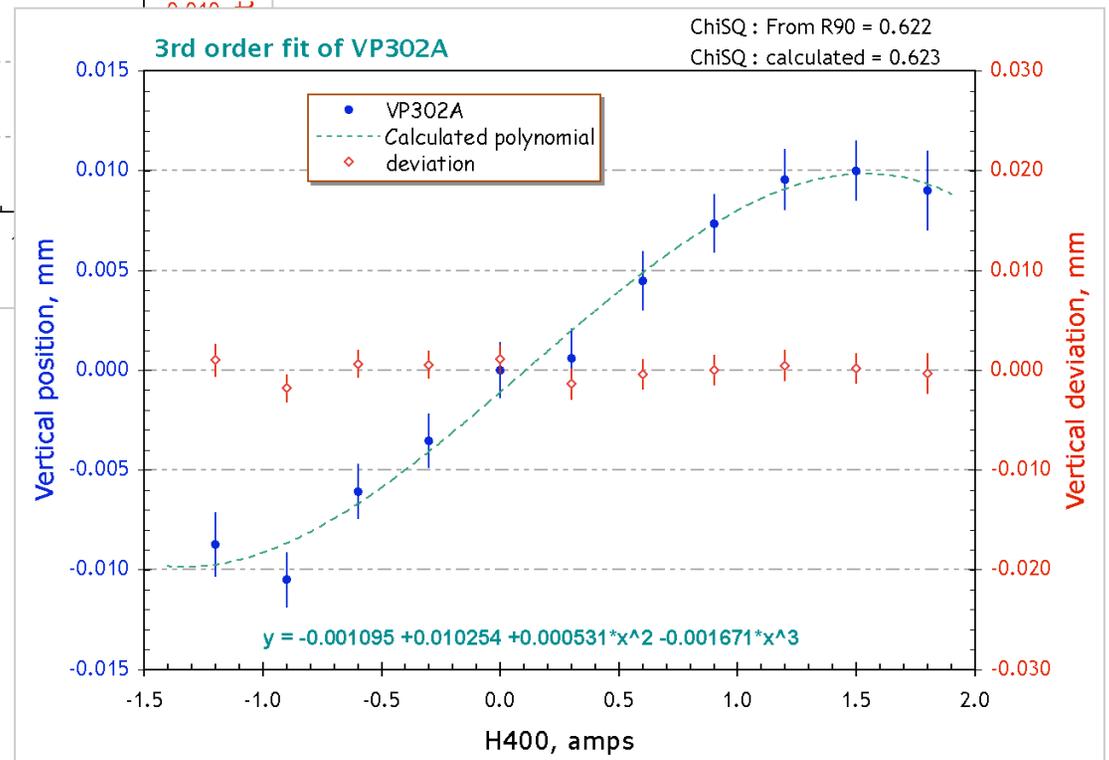
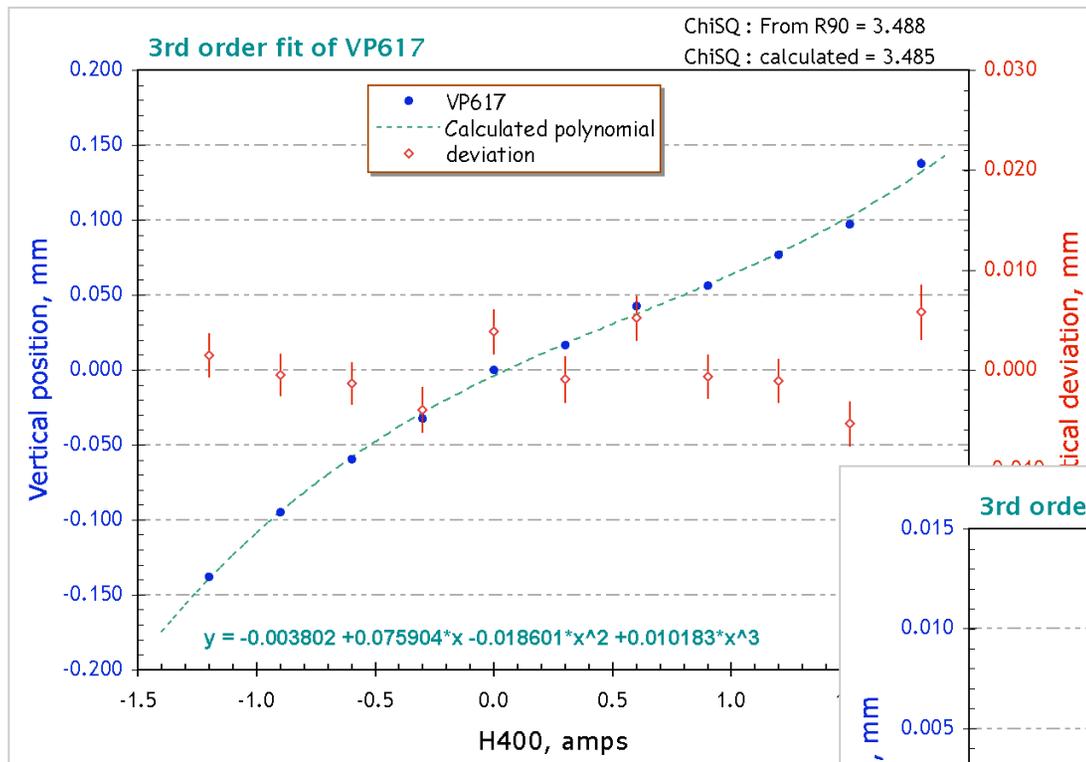
HP504 & HP508 response to H402 3-bump



VP109 & VP427 response to H402 3-bump



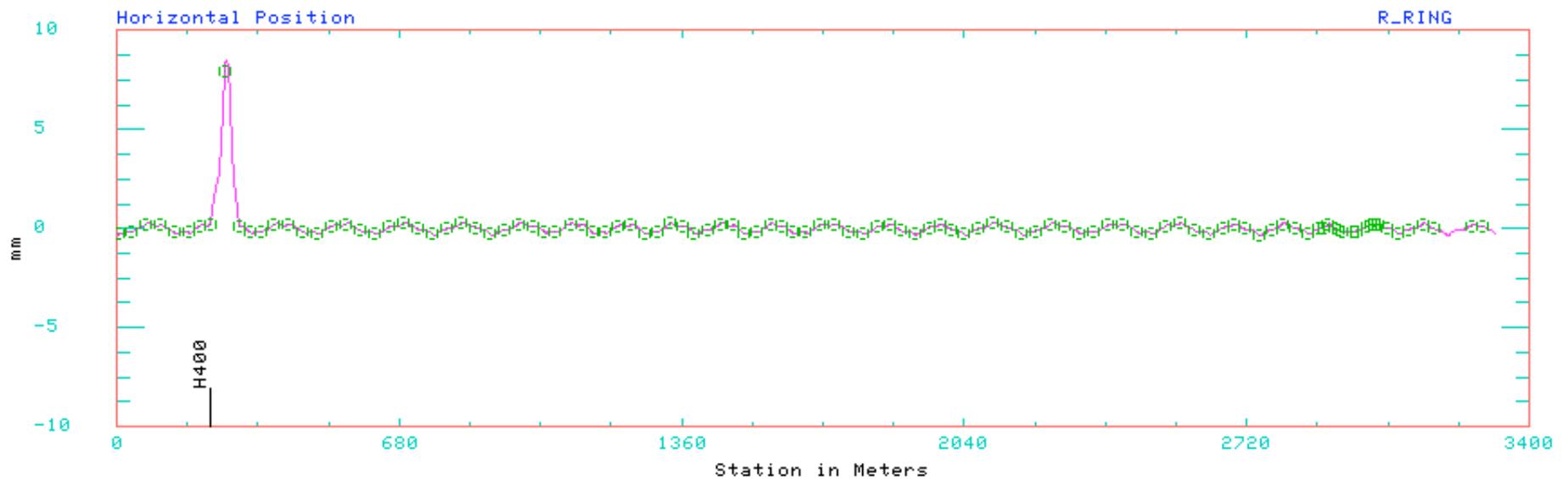
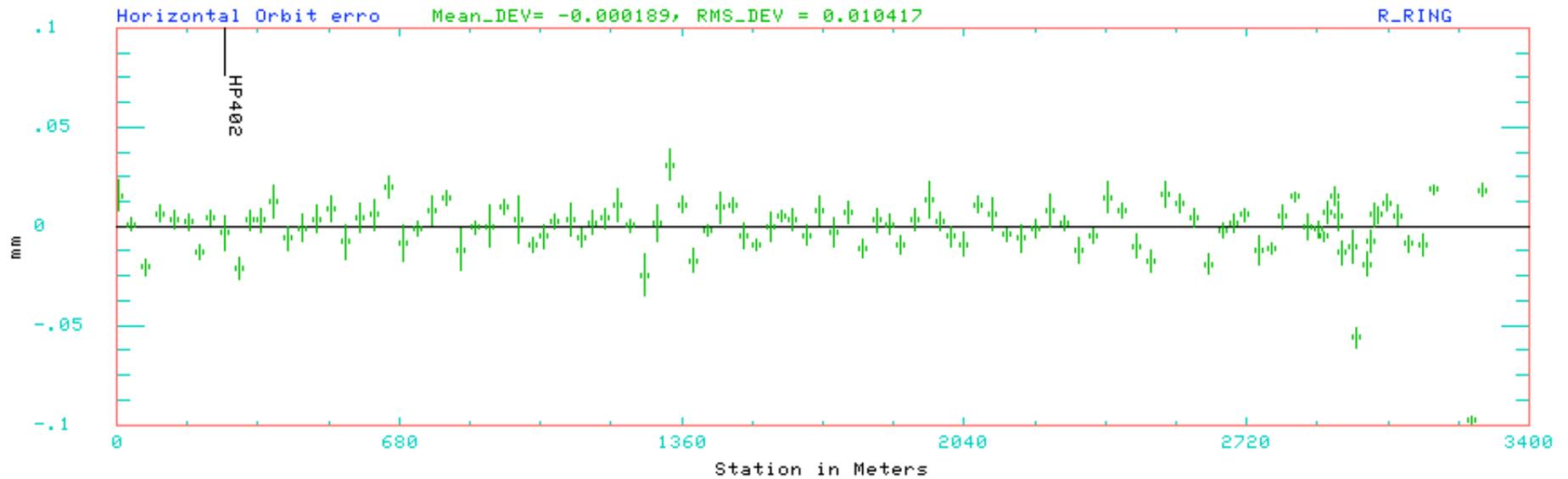
VP302A and VP617 responses to H402 3-bump



3-bump orbit analysis

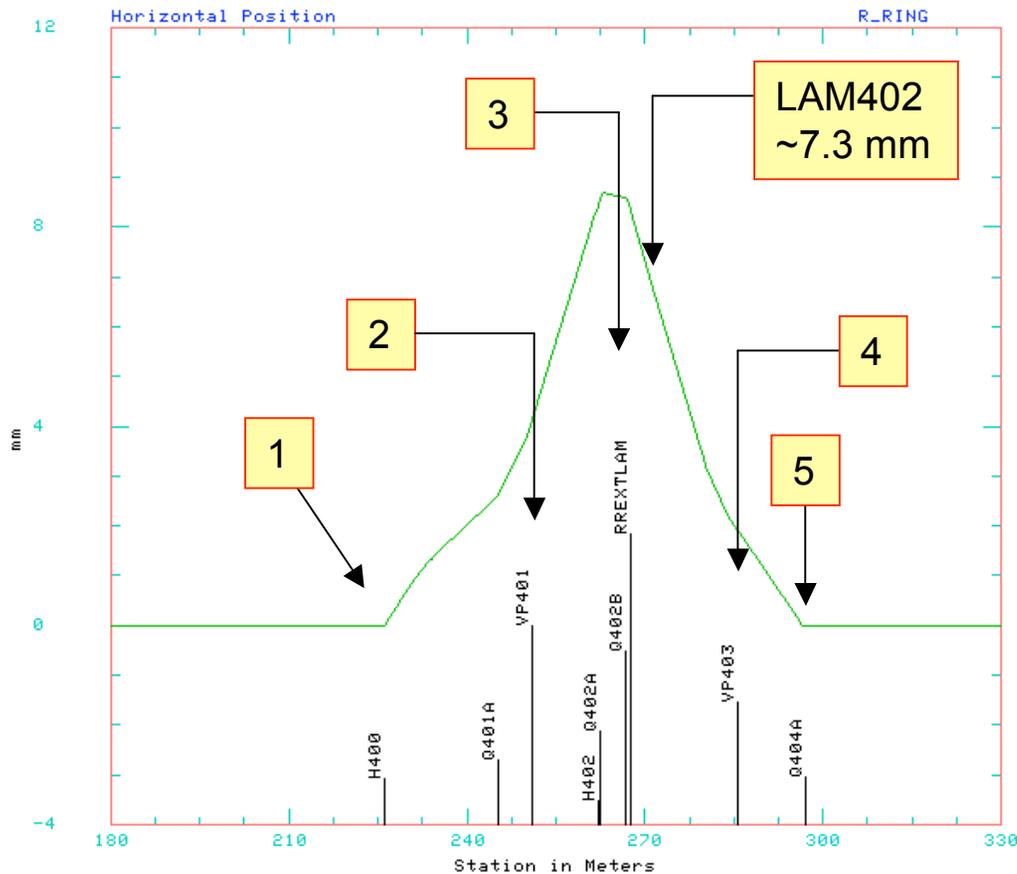
- **I90**
 - 3rd order polynomial fit to position data
 - ✓ w.r.t. kick from leading trim dipole in the bump.
 - Use polynomial coefficient as orbit, of a chosen order
 - ✓ And save into R39 BPM file.
 - Calculate and match the measured 3-bump orbit.
 - ✓ Get estimated displacement at the trouble location.
- **R49, using "Magnet Move" option**
 - Read coefficient orbit from R39 BPM file.
 - Send data to MICADO for fitting.
- **Convert kick error into multipole strengths**
 - Get integrated field from kick amplitudes.
- **Both horizontal and vertical plane responses.**
 - For normal and skew components.

H402 3-bump first order orbit, in mm/amp



What we get with closed 3-bump data

Using H402:3 bump as an example



Vertical kick sources implies:

Location 1 & 5:

- Rolled trim dipoles

Location 3:

- Skew quad
- Rolled trim dipole

Excessive vertical BPM position readings

Location 2 & 4

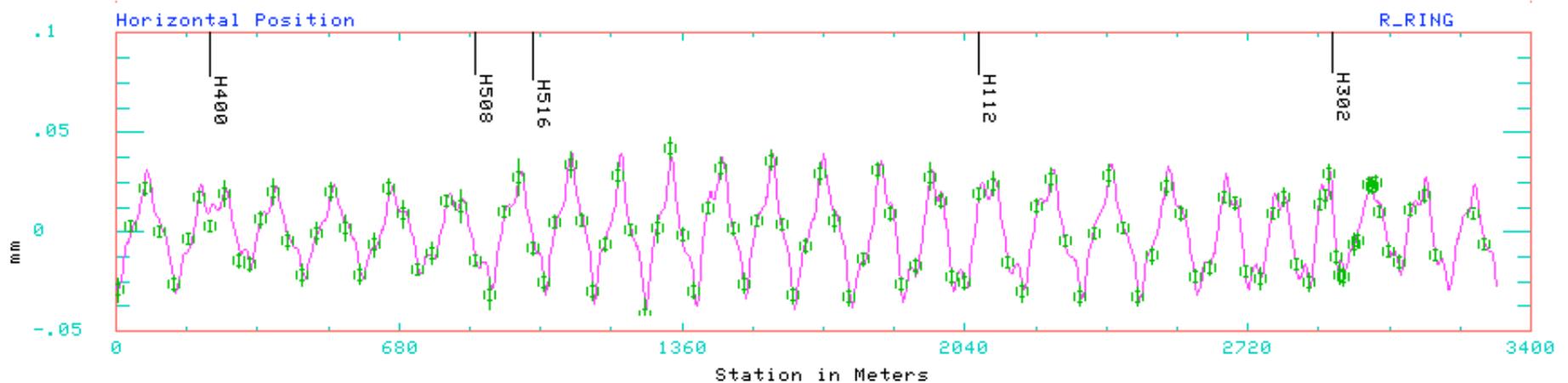
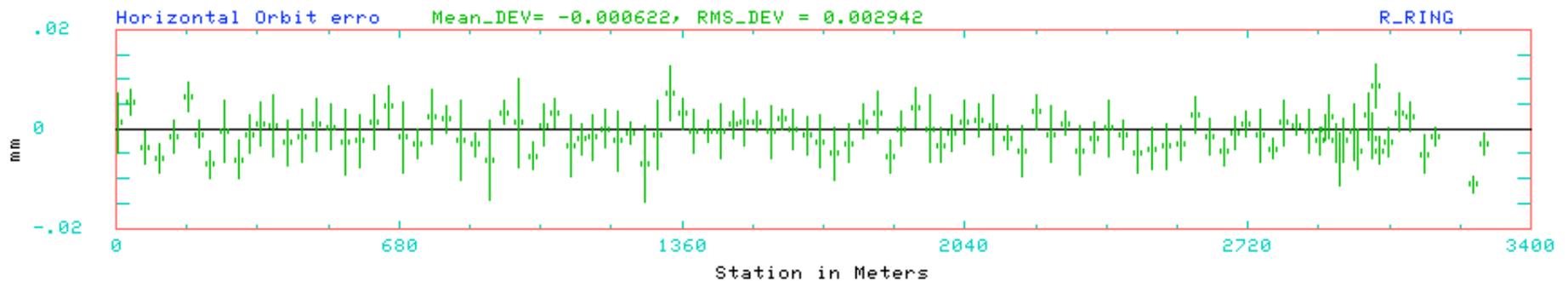
- Rolled BPMs.

H402 3-bump 2nd order, horizontal

Fit result

	Old	Delta	New
H402:3, horz 2nd orde, x100			
R:H112	1.182	0.124	1.306 A
R:H302	-3.144	-0.327	-3.472 A
R:H400	-0.230	-0.548	-0.778 A
R:H508	0.288	0.177	0.465 A
R:H516	-1.027	0.146	-0.881 A

<Return>

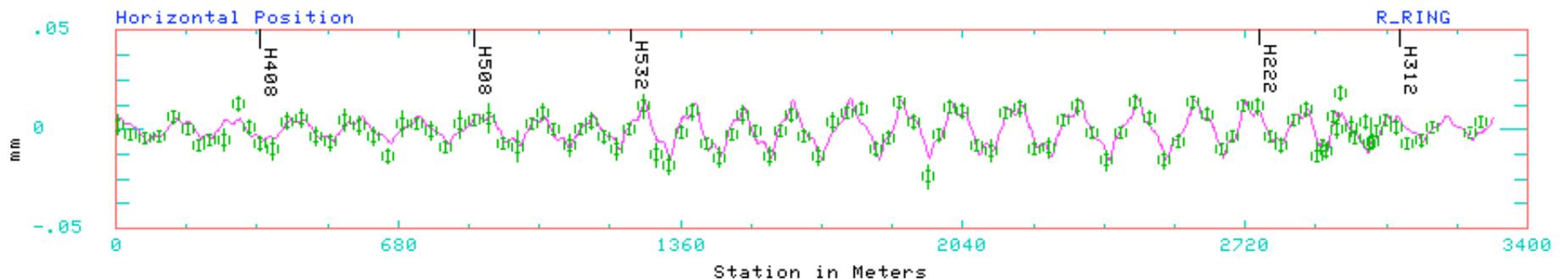
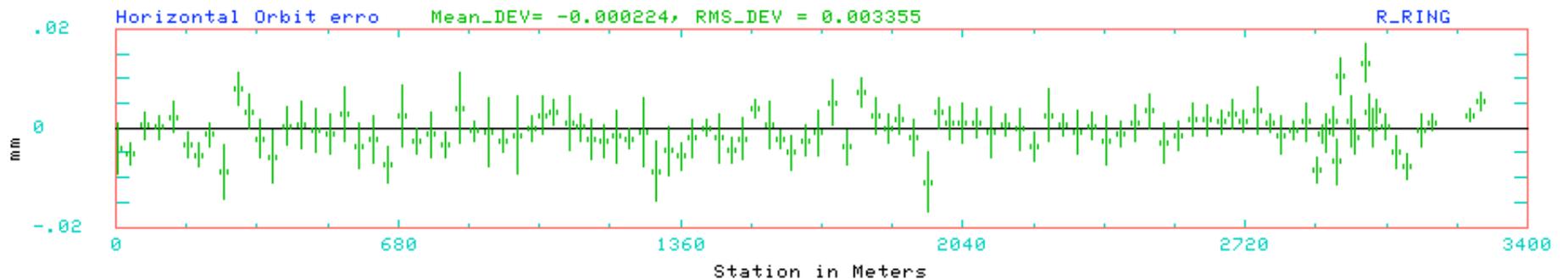


H402 3-bump 3rd order, horizontal

Fit result

H402:3, horz 3rd	Old	Delta	New	
R:H222	0.595	-0.072	0.523	A
R:H312	-0.598	-0.156	-0.755	A
R:H408	-0.137	0.146	0.009	A
R:H508	0.288	-0.094	0.194	A
R:H532	-0.038	-0.110	-0.148	A

<Return>



H402 3-bump 1st order, vertical

Magnet Movement

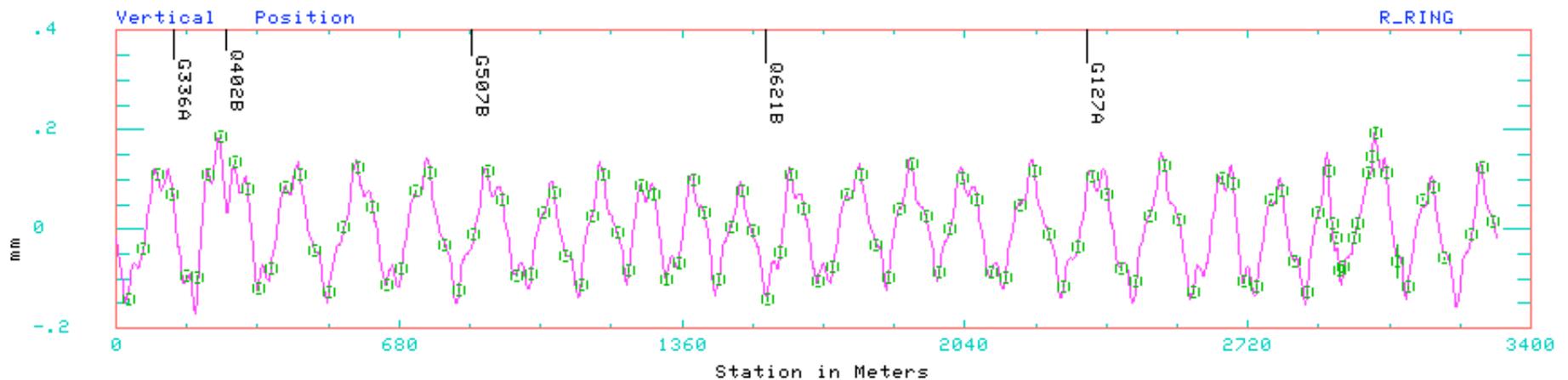
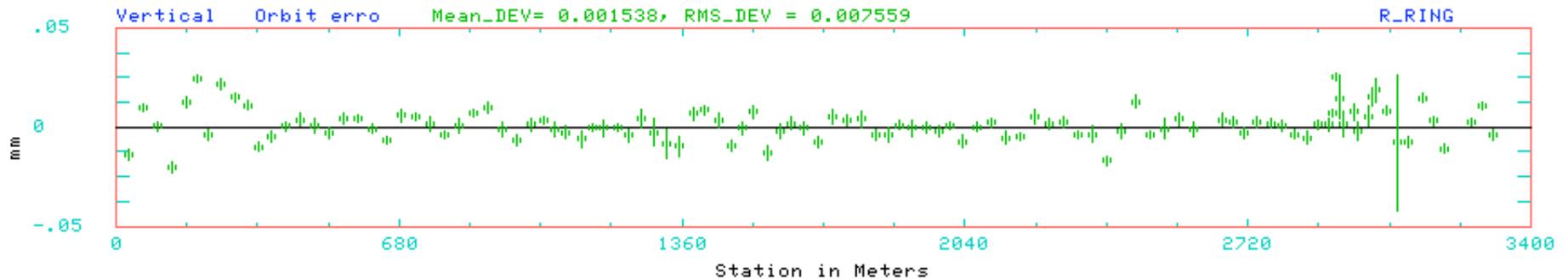
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H402:3, vert 1st, x10
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	mrad	mm	mils
G127A	-0.00404	-0.0822	-3.2
G336A	0.01426	-0.2802	-11.0
Q402B	-0.11452	2.5443	100.2
G507B	0.00204	0.0417	1.6
Q621B	0.00376	0.0866	3.4

<Return>

Orbit sent to MICADO was magnified 10 times for better accuracy.

Attributing kick error to skew quadrupole in LAM402

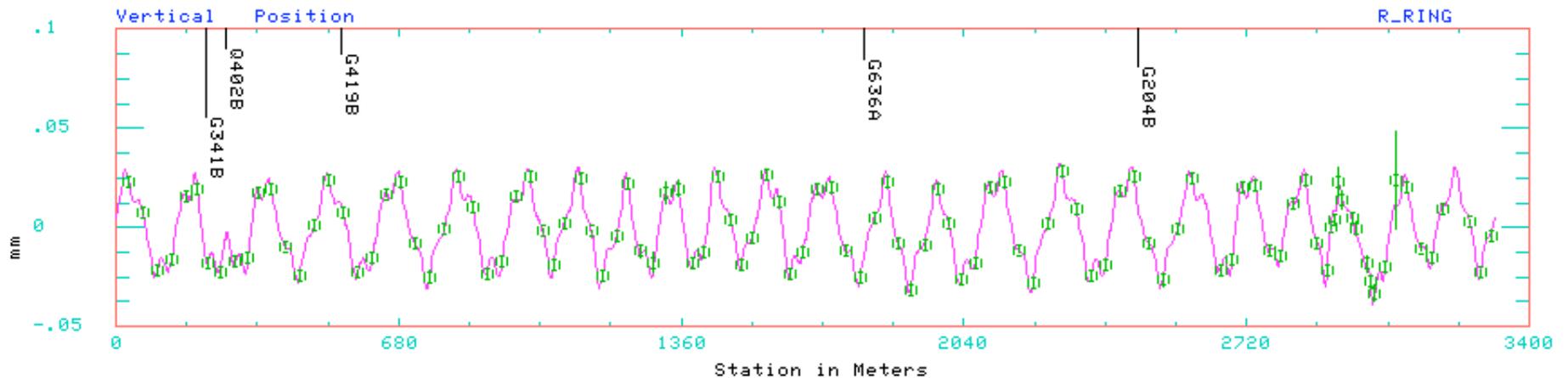
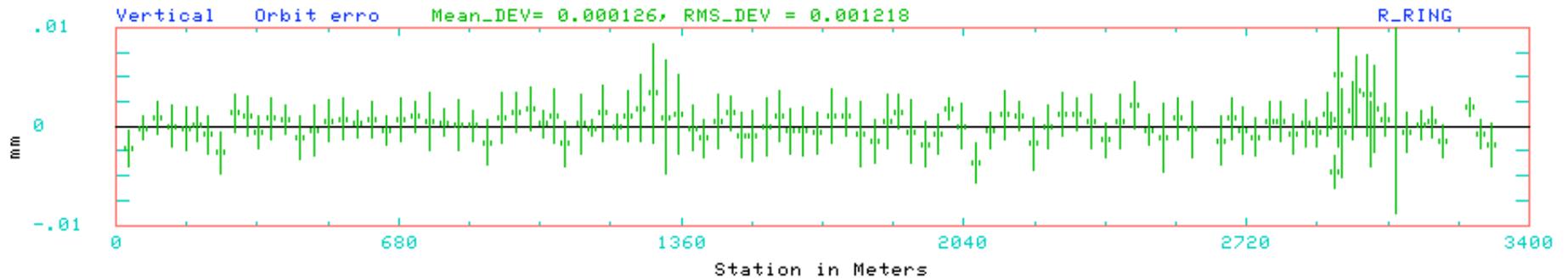


H402 3-bump 2nd order, vertical orbit

```
Magnet Movement
H402:3, vert 2nd
      , x100
      mrad      mm      mils
G204B      -0.01007  0.1980   7.8
G341B      -0.01516 -0.2125  -8.4
Q402B       0.19340 -4.2969 -169.2
G419B       0.00552  0.1124   4.4
G636A      -0.01290  0.2536  10.0
<Return>
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Orbit sent to MICADO was magnified 100 times for better accuracy.

Attributing 2nd order kick error to skew sextupole in LAM402



H402 3-bump 3rd order vertical orbit

Magnet Movement

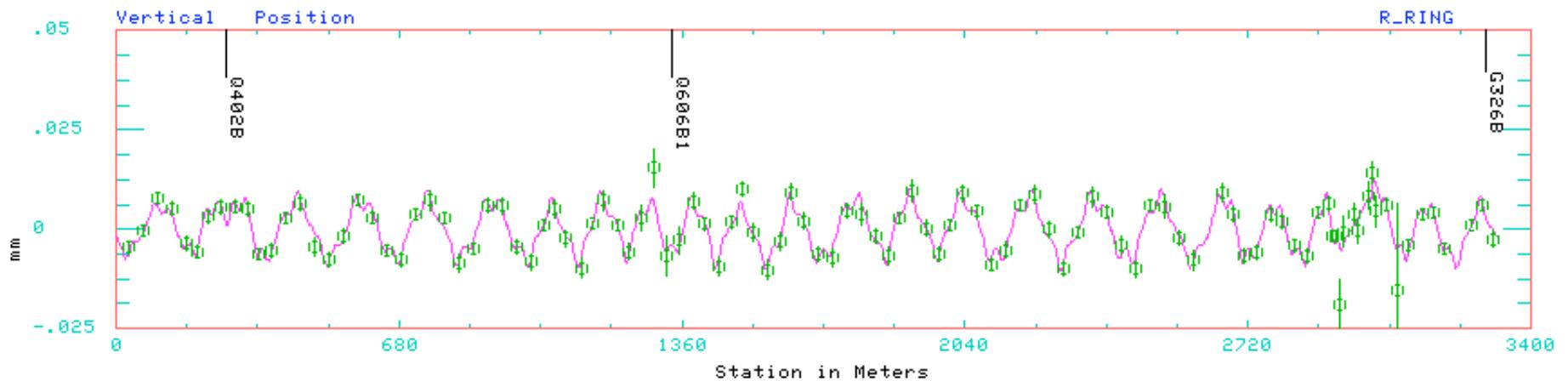
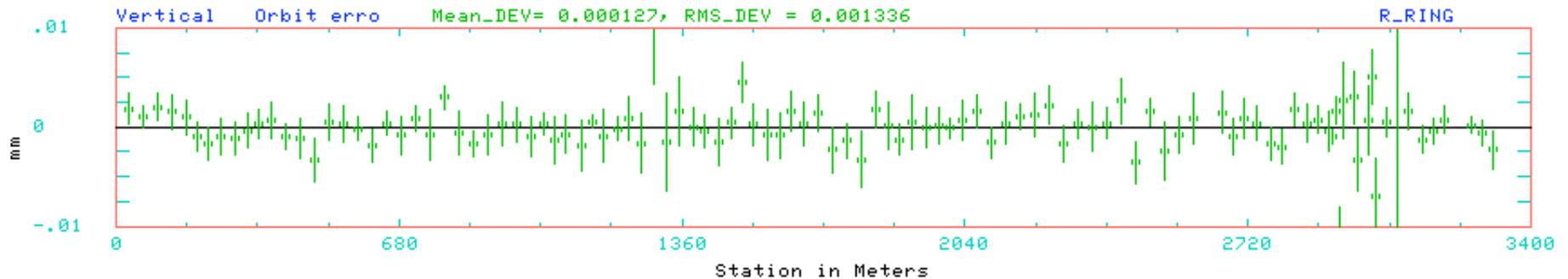
H402:3, vert 3rd

	mrad	mm	mils
G326B	-0.00954	0.1876	7.4
Q402B	-0.06135	1.3631	53.7
Q606B1	-0.01113	0.3893	15.3

<Return>

Orbit magnified 100 times.

Attributing 3rd order kick error to skew octupole in LAM402.



Implicated multipole fields at Lam402

Fitted kick error from MICADO

Effective integrated field

H402	Δm_r	$\Delta B_L, G-M$	$B(n)L$	$B(n)$			MTF units
Horz 1st	-0.0112	-3.3258	-0.4548	-0.1119	KG/M	Norm. quad	-18.685
Horz 2nd	0.0000	0.0000	0.0000	0.0000	KG/M ²	Norm. sext.	0.000
Horz 3rd	0.0000	0.0000	0.0000	0.0000	KG/M ³	Norm. Oct.	0.000
Vert 1st	-0.0115	-3.3956	-0.4643	-0.1143	KG/M	skew quad	-19.077
Vert 2nd	0.0019	0.5734	21.3581	5.2554	KG/M ²	skew sext.	11.144
Vert 3rd	-0.0006	-0.1819	-2756.8000	-678.3464	KG/M ³	skew oct.	-12.179

Integrated multipole strength,
Factoring in bump displacement
at LAM402

Multipole field strength

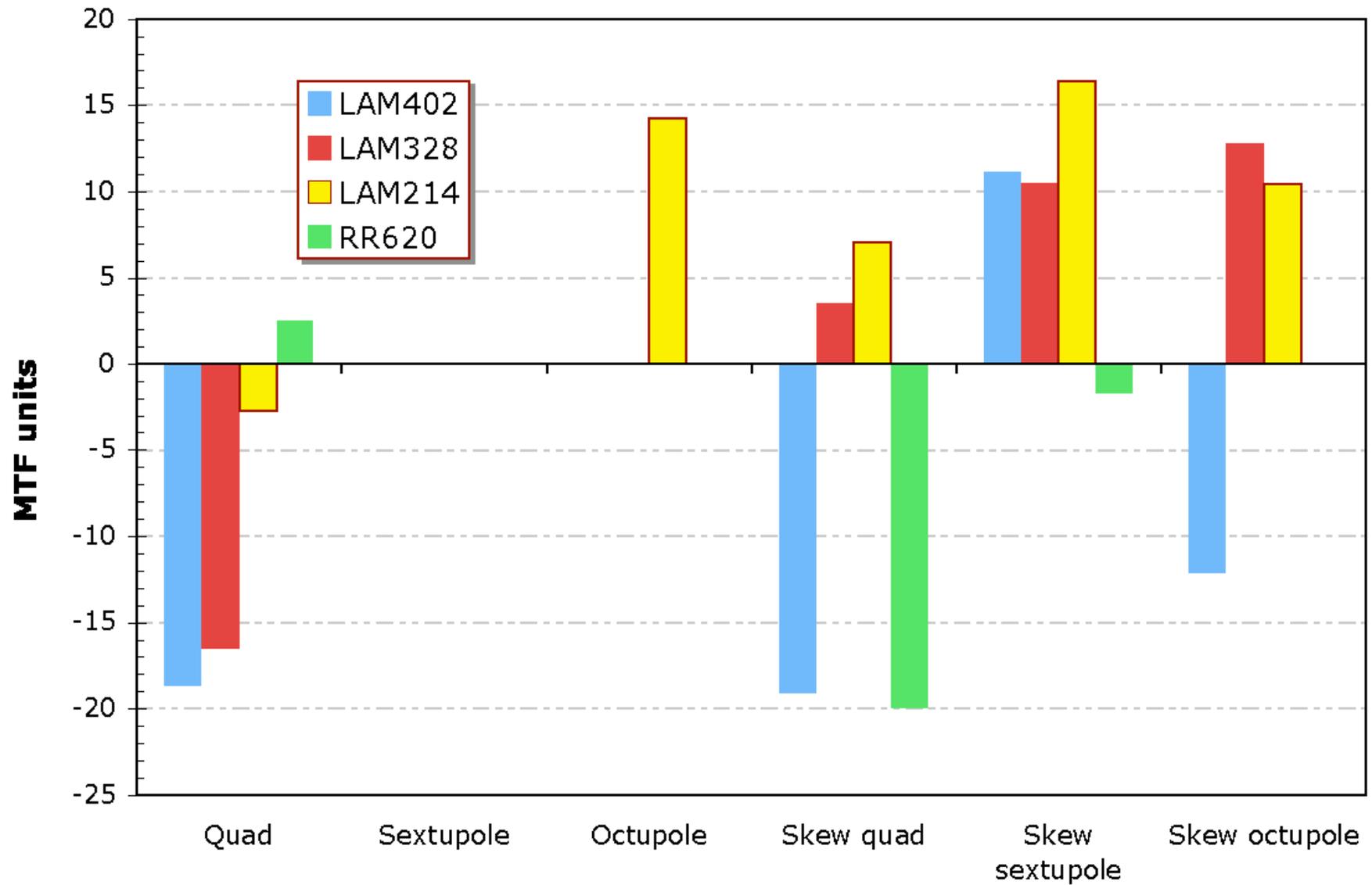
Implied multipole fields for other locations

H328	$\Delta m r$	$\Delta B L, G-M$	$B(n)L$	$B(n)$			MTF units
Horz 1st	-0.0050	-1.4702	-0.4023	-0.0990	KG/M	Norm. quad	-16.527
Horz 2nd	0.0000	0.0000	0.0000	0.0000	KG/M ²	Norm. sext.	0.000
Horz 3rd	0.0000	0.0000	0.0000	0.0000	KG/M ³	Norm. Oct.	0.000
Vert 1st	0.0011	0.3154	0.0863	0.0212	KG/M	skew quad	3.545
Vert 2nd	0.0005	0.1355	20.1407	4.9559	KG/M ²	skew sext.	10.509
Vert 3rd	0.0001	0.0241	2898.1153	713.1189	KG/M ³	skew oct.	12.803

H214	$\Delta m r$	$\Delta B L, G-M$	$B(n)L$	$B(n)$			MTF units
Horz 1st	-0.0010	-0.2892	-0.0659	-0.0162	KG/M	Norm. quad	-2.707
Horz 2nd	0.0000	0.0000	0.0000	0.0000	KG/M ²	Norm. sext.	0.000
Horz 3rd	0.0002	0.0464	3222.5157	792.9419	KG/M ³	Norm. Oct.	14.236
Vert 1st	0.0025	0.7540	0.1718	0.0423	KG/M	skew quad	7.057
Vert 2nd	0.0010	0.3049	31.4339	7.7347	KG/M ²	skew sext.	16.401
Vert 3rd	0.0001	0.0340	2362.4914	581.3217	KG/M ³	skew oct.	10.437

H620	$\Delta m r$	$\Delta B L, G-M$	$B(n)L$	$B(n)$			MTF units
Horz 1st	0.0009	0.2809	0.0613	0.1207	KG/M	Norm. quad	2.519
Horz 2nd	0.0000	0.0000	0.0000	0.0000	KG/M ²	Norm. sext.	0.000
Horz 3rd	0.0000	0.0000	0.0000	0.0000	KG/M ³	Norm. Oct.	0.000
Vert 1st	-0.0075	-2.2270	-0.4861	-0.9570	KG/M	skew quad	-19.973
Vert 2nd	-0.0001	-0.0353	-3.3607	-6.6156	KG/M ²	skew sext.	-1.754
Vert 3rd	0.0000	0.0000	0.0000	0.0000	KG/M ³	skew oct.	0.000

Multi-pole fields in MTF unit



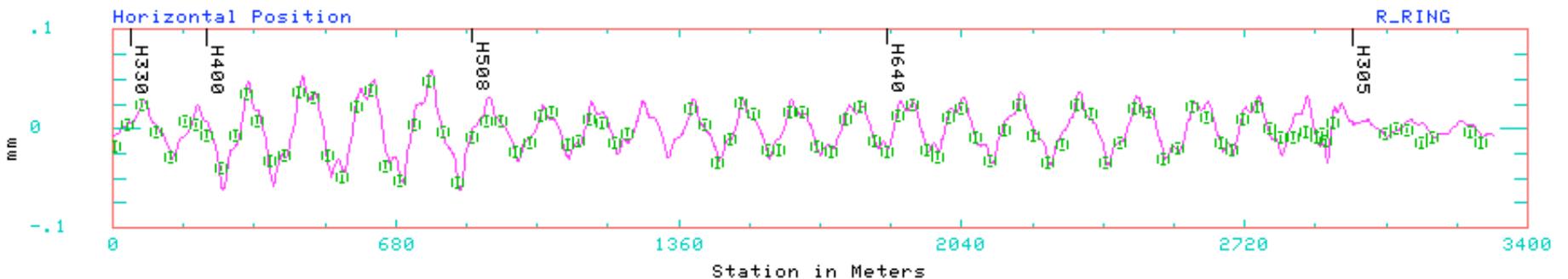
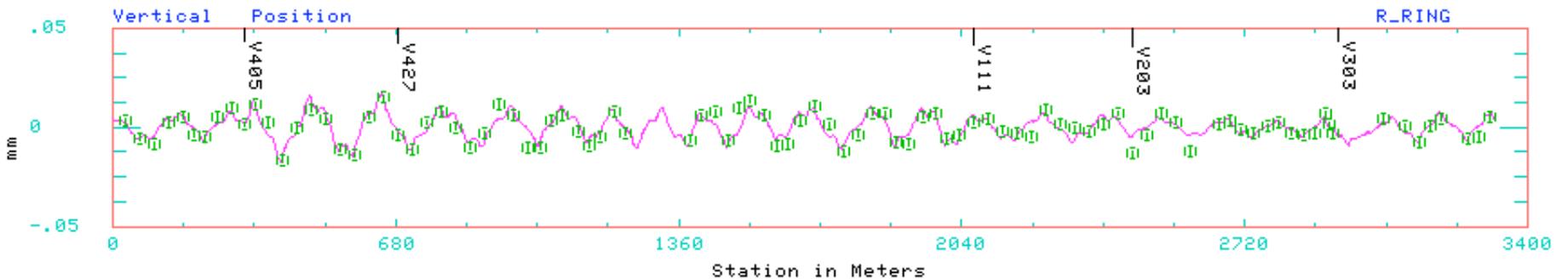
Differences between nominal orbits

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R:H330  Amps  0          .00414   0
R:H400  Amps  0         -.00361   0
R:H508  Amps  0         -.00552   0
R:H640  Amps  0          .00199   0

R:V111  Amps  0         -.00179   0
R:V203  Amps  0          .0018    0
R:V303  Amps  0         -.00227   0
R:V405  Amps  0          .00834   0
R:V427  Amps  0          .00177   0

<Exit>      1:13 of 25
```

H trim: 0.117 mr/amp
V trim: 0.074 mr/amp
H305: 0.287 mr/amp



Summary

- **Analysis**
 - Data is limited by the corrector stability.
 - Not all data sets are analyzed.
- **Result**
 - Consistent with result from previous study.
 - Found evidence of multipole field errors
 - ✓ skew quadrupole, skew sextupole and octupole fields.
 - RR620 is consistent with rolled quads.
- **Misc**
 - Of the 3 Lambertson locations 214 has the smallest horizontal aperture.
- **Simulation**
 - In progress to update R90
 - ✓ Handles multipole with both normal and skew components.